N°. XLI.

Calculations relating to Grist and Saw Mills, for determining the quantity of Water necessary to produce the desired effect when the Head and Fall are given in order to ascertain the dimensions of a new invented Steam Engine, intended to give motion to Water-wheels in places where there is no Fall, and but a very small Stream or Spring. By JOHN NANCARROW.

ELEMENTS used in the following calculations, so far as they relate to works moved by water-wheels:

1. let $h =$ mean height of the head of water in the penstock.
2. $a =$ the area of the aperture or gateway.
3. $q = 6.128 =$ the number of ale gallons in a cubic foot.
4. $s = 16$ feet, $=$ the space a heavy body falls from rest in one second.
5. $2s =$ the uniform velocity acquired by falling 16 feet from rest.
6. $2\sqrt{hs}$, or $8\sqrt{h} =$ the uniform velocity acquired by falling from rest any depth $= h$.
7. $8aq\sqrt{h}$, the number of ale gallons issuing through any aperture a in one second, and $8aqt\sqrt{h} =$ the quantity in t seconds.
8. $8a\sqrt{h} =$ the number of cubic feet flowing through a in one second, and $8at\sqrt{h} =$ the number of cubic feet in t seconds.
9. $w = 62.5$ pounds avoirdupoise, $=$ the weight of a cubic foot of water, and 10.2 lbs. $=$ the weight of an ale gallon.
10. $haw =$ the weight of any column of water.
11. $\frac{\sqrt{h}}{4} = t =$ the time of falling from an height $= h$.
12. $D - \frac{d}{2}$ is the common practical rule for finding the mean height of the head of water when the aperture is vertical and rectangular where D represents the depth of

of water in the penſtock, and d the height of the gateway, and is only an approximation, though very near the truth; the genuine method derived from the parabola is as follows:

Let ABCD Fig. 1. repreſent a large ciſtern or penſtock, and MKLN an orifice made in one of its ſides.

When the upper edge of the gateway, as KL is below the ſurface of the water in the penſtock, the ſum of all the velocities or ſheets of water which flow through it, being expreſſed by the elements of the ſegment of a parabola FHIG, there will be found amongſt them a mean ordinate OT, which being multiplied by the height HP, will give a product equal to the area of this ſegment. Now, in order to determine the mean height EO, let EP$=a$, EH$=b$, HP$=c$, and the mean height EO$=x$. The ſum of all the velocities, or the area of the parabola EPG will be $\frac{2a}{3}\sqrt{a}$, and the ſum of all the velocities acquired by falling from E to H $= \frac{2b}{3}\sqrt{b}$; conſequently $\frac{2a}{3}\sqrt{a} - \frac{2b}{3}\sqrt{b}$ will give the ſum of all the velocities which flow through the orifice MKLN, which is equal to the parabolic ſegment HPIG, or to the product of the mean velocity $\sqrt{EO}$ (x) by the height HP (c), hence we have $\frac{2a}{3}\sqrt{a} - \frac{2b}{3}\sqrt{b} = c\sqrt{x}$, which equation being reduced will give $x = \frac{4}{9} \times \frac{a^3+b^3-2ab\sqrt{ab}}{cc}$.

EXAMPLE.

If the height EP (a) be $= 8$ feet, EH (b) $= 6$ feet, then will HP or $c = 2$ feet; and by ſubſtituting theſe numbers for their reſpective values in the above equation, x will be found $=$ 6.99 feet.

By the common practical rule, (ſee article 12,) D $- \frac{d}{2} = b = x$, where D$=8$ and $d=2$; conſequently $b = 7$ feet, whence it appears that $a - \frac{c}{2} = D - \frac{d}{2}$ is ſufficiently exact for all common purpoſes.

In

In the foregoing elements (ſee art. 4 and 5.) I have ſuppoſed the ſpace which a heavy body deſcribes by falling from reſt in one ſecond of time to be 16 inſtead of $16\frac{1}{12}$ feet, and the uniform velocity acquired by ſuch fall = 32 feet; whereas every author which I have read, (even on the ſubject of hydraulics) makes it $32\frac{1}{6}$ feet, without allowing for the friction the water is ſubjected to in its paſſage through the aperture or gateway, or for the reſiſtence it meets with by its ſudden impulſe againſt the air, immediately on its leaving the penſtock. It evidently follows that the uniform velocity muſt be diminiſhed on both theſe accounts: hence we may ſafely conclude, that a uniform velocity of 32 feet in one ſecond, will be found to coincide with an experimental proof, nearer than that of $32\frac{1}{6}$ feet in the ſame time.

Before the dimenſions of the ſteam engine can be aſcertained, it is eſſentially neceſſary to know what quantity of water it muſt deliver into the penſtock in a given time, in order that the power or force by which the water-wheel is moved, may be at leaſt adequate to the purpoſe intended. Several griſt and ſaw-mills have been examined with this view, and ſuch meaſurements carefully taken as were thought neceſſary for determining the powers by which they are moved. Amongſt theſe we have ſelected John Beydler's griſt and ſaw-mills, and a ſaw-mill belonging to Chriſtopher Keyger, both in the county of Berks and ſtate of Pennſylvania.

Calculation of the power applied to Beydler's grist-mill, either for one or two pair of stones, each being $4\frac{1}{2}$ feet in diameter, and that of the water-wheel 16 feet; the top of which is nearly on a level with the bottom of the penstock, and grinds from 50 to 60 buſhels of wheat in 12 hours, with a ſingle pair of stones.

THE head or depth of water from its ſurface to the bottom of the penſtock for working one pair of ſtones = 22 inches.

The gateway or aperture a is 30 inches wide by $1\frac{1}{2}$ inch deep = 45 inches = 0.3125 parts of a ſquare foot.

Mean height of the head, or $D - \frac{d}{2} = h$ (art. 12.) $= 21\frac{1}{4}$ inches = 1.77 feet.

By art. 7th we have $8aq\sqrt{h}$ = the number of ale gallons iſſuing through any aperture a in one ſecond, $= 8 \times 0.3125 \times$ 6.128

6.128×1.33 ($\sqrt{h}$) $= 20.38$ gallons of water flowing through the gateway in one ſecond of time. The number of cubic feet which iſſue through this aperture in the ſame time $= 8a\sqrt{h}$ (art. 8.) $= 8 \times 0.3125 \times 1.33 = 3.325$, which being multiplied by 62.5 pounds, the weight of a cubic foot of water, gives 207.8 lbs. for the whole preſſure on the upper part of the wheel during the ſpace of one ſecond; but the inſtantaneous preſſure, or force of impact, where the water firſt ſtrikes the wheel, is haw (art. 10.) $= 1.77 \times 0.3125 \times 62.5 = 34.57$ pounds; alſo $8\sqrt{h} =$ the uniform velocity acquired at *a* the aperture in a ſecond, $= 10.64$ feet.

When this mill drives two pair of ſtones, the gate is raiſed an half inch higher; h being in this caſe $= 1.75$ and $\sqrt{h} = 1.323$ feet, by which means a becomes $= 30 \times 2$ or 60 ſquare inches, $=$ 0.417 parts of a ſquare foot. The other meaſurements remaining the ſame as above, we ſhall have

$8aq\sqrt{h} = 27$ gallons per ſecond,

$8a\sqrt{h} = 4.414$ cubic feet per do.

$haw = 46.5$ pounds for the force of impact,

and $8\sqrt{h} = 10.584$ feet for the uniform velocity per ſecond.

In Emerſon's Mechanics, and Fletcher's Univerſal Meaſurer and Mechanic, the uniform velocity acquired by falling from an height $= h$, is denoted by $\sqrt{2hs}$ inſtead of $2\sqrt{hs}$, which is the true meaſure of its celerity. This circumſtance is not mentioned with the leaſt view to find fault with theſe authors, but to remove any doubts which may ariſe in the minds of ſuch as are diſpoſed to peruſe theſe calculations.

BEYDLER's SAW-MILL.

This mill has a ſmall underſhot wheel, commonly called a flutter wheel, which is no more than 3 feet in diameter. The depth of the water from its ſurface to the bottom of the penſtock is 3 feet, the gateway is 3 feet wide by 6 inches deep, $= 1.5$ ſquare foot, the mean height of the head or $D - \frac{d}{2} = 2.75$ feet $= h$, and $\sqrt{h} = 1.658$. The fall from the bottom of the penſtock to the place where the water impinges on the float or ladle-board is 10 feet, and $2.75 + 11 = 13.75$, being equal to the whole height

height of the column of water which propels this wheel. Now by art. 7. we have $8aq\surd h =$ the quantity of water which flows through the gateway in one ſecond, $= 8\times 6.128\times 1.5\times 1.658 = 121.92$ gallons. Again, $haw = 2.75\times 1.5\times 62.5 = 257.8$ pounds, which is equal to the weight of the column preſſing againſt the aperture; alſo $8\surd h = 13.264$ feet, the uniform velocity of the water every ſecond as it iſſues through the gateway.

In order to find the force of impact on the wheel, we muſt, in the firſt place determine (what may be called) the initial weight of the water, or that with which it may be ſuppoſed to begin to preſs at its ſurface in the penſtock, viz. by dividing the momentum by the uniform velocity; but $haw = 257.8$ is the momentum at the aperture or gateway, and $13.264 =$ the uniform velocity: therefore $\frac{257.8}{13.264} = 19.406$ lbs. $=$ W, the initial weight required $= \frac{haw}{8\surd h} = \frac{aw}{8}\surd h$; conſequently $8W\surd h$ will expreſs the force of impact ſought, h being now $= 13.75$ and $\surd h = 3.708$; hence $8W\surd h = 8\times 19.406\times 3.708 = 575.66$ pounds for the conſtant impelling force on the ladle-board; but $575.66 = haw$, and $a = \frac{575.66}{hw} = \frac{575.66}{13.75\times 62.5} = 0.67$ parts of a ſquare foot. To prove the truth of the above method for finding the force of impact, we need only try whether $8aq\surd h$ (where $h = 13.75$ and $a = 0.67$) will produce the ſame number of gallons as that before found, viz. 121.9 in one ſecond. In the preſent caſe $8aq\surd h = 8\times 0.67\times 6.128\times 3.708 = 121.8$ being nearly the ſame as found above, and is a ſufficient proof that the force of impact where the water impinges on the wheel is rightly determined.

KEYGER's SAW-MILL.

This ſaw-mill is over-ſhot, the wheel 12 feet diameter, the penſtock is 6 feet in depth by 2 feet wide, and when I ſaw it at work, there were only 4 feet and 1-4th inch of water in the ciſtern, although the ſaw moved at the rate of 120 ſtrokes in a minute, whilſt it paſſed through a piece of oak at leaſt 12 inches deep.

deep, and the gateway no more than half an inch high. Hence $h = 4$, and $\sqrt{h} = 2$ feet. The aperture $a = 24 \times 0.5 = 12 = 0.0833$ parts of a ſquare foot; wherefore $8aq\sqrt{h} = 8 \times 0.0833 \times 6.128 \times 2 = 8.2$ gallons which falls on the wheel in the ſpace of one ſecond, $8a\sqrt{h} = 8 \times 0.0833 \times 2 = 1.32$ cubic feet in the ſame time, and $8\sqrt{h} = 16$ feet, the uniform velocity per ſecond, as the water leaves the aperture; alſo $haw = 4 \times 0.0833 \times 62.5 = 20.8$ pounds for the force of impact where the water firſt enters on the wheel. When this mill is ſupplied with a 6 feet head, and the gate drawn up one inch, the ſaw makes 180 ſtrokes in a minute through an oak log 18 inches deep. We have now $h = 6$, $\sqrt{h} = 2.45$ feet, and $a = 24$ inches $= 0.167$ parts of a ſquare foot. Here $8aq\sqrt{h} = 8 \times 0.167 \times 6.128 \times 2.45 = 20$ gallons per ſecond, $8a\sqrt{h} = 8 \times 0.167 \times 2.45 = 3.273$ cubic feet in the ſame time, and $8\sqrt{h} =$ the uniform velocity acquired by a fall of 6 feet; alſo $haw = 6 \times 0.167 \times 62.5 = 62.6$ for the weight of the column or force of impact on the wheel.

I have been the more particular in making theſe calculations in order to aſcertain the dimenſions of the ſteam-engine for various purpoſes; on which account we muſt again have recourſe to the parabola, and alſo to the inverted ſyphon.

To find the retarded velocity and time of aſcent of water into an exhausted receiver, through a vertical pipe or tube, by the aſſistance of the parabola. Fig. 2.

Let CBFG be an inverted ſyphon, the diameter being every where equal, accompanied with a cock T, and the firſt branch AE always kept full of water: it is certain that if all the reſt of the ſyphon be empty, and the cock be ſuddenly opened, the water will immediately ruſh into the tube of communication VX with a uniform velocity equal to that which a heavy body would acquire by falling from A to B, and will be continually diminiſhed in proportion as the ſecond branch is filled.

To ſhew in what order this retardation of the water diminiſhes its velocity at any point Q of the tube GS, where it is ſuppoſed to be aſcending towards qr, we muſt deſcribe on the lines AB, CD as an axis with the ſame parameter, two equal parabolas CPH and BKI, ſituated in oppoſite directions. Complete the parallelogram AM, and draw as many lines LR as

you pleaſe parallel to the horizontal line IG. Now if we take the ordinate AI, or its equal DH to expreſs the whole uniform velocity acquired by falling from C to D, it is evident that the ordinate OP will denote the velocity at the point O, acquired by a fall equal to CO, and the ordinate NK will expreſs the velocity ariſing from a fall equal to NB or QS. But we ſhall prove that the velocity of the aſcending water in the ſecond branch, when it arrives at Q, ought not to be expreſſed by the ordinate which correſponds to it; but by the line LK, the difference between the entire uniform velocity LN or MB (by falling from A to B) and that of NK.

To demonſtrate that the height QS or NB of the water in the tube SR, is equal to a fall which can produce the relative velocity ariſing from CD, or the difference between the velocities acquired by falling from A to B, and that of the aſcending water at Q; let AB and QS be conſidered as two non-elaſtic bodies, whoſe momenta are as the altitudes AB and QS. If AB $= a$ and QS $= r$, we ſhall have $a = \sqrt{a} \times \sqrt{a}$, and $r = \sqrt{r} \times \sqrt{r}$; but the difference of the momenta divided by the ſum of the bodies is equal to the velocity, which let be v; therefore $\sqrt{a} \times \sqrt{a} - \sqrt{r} \times \sqrt{r}$ divided by $\sqrt{a} + \sqrt{r} = \dfrac{\overline{\sqrt{a}+\sqrt{r}} \times \overline{\sqrt{a}-\sqrt{r}}}{\sqrt{a}+\sqrt{r}} =$ $\sqrt{a} - \sqrt{r} = v =$ LK, the velocity of the water at Q, and $\sqrt{a} - v = \sqrt{r}$, which is the relative velocity produced by a fall equal to QS. As this velocity is expreſſed by the ordinate NK, the difference between it and MB or LN will expreſs the retarded velocity of the water in the tube of communication DX, which is the ſame as that of the ſurface QR at the point Q.

As it will be the ſame with all the retarded velocities during the time employed in filling the tube GF, it follows that their ſum will be expreſſed by that of all the ordinates, or the area of the parabolic complement MIKB.

Before the obſervations of Belidor on the inverted ſyphon, in his theory relating to the common ſucking pump, it was cuſtomary to eſtimate this ſum by the area of the parabola DCPH or ABKI; for the velocity at Q was expreſſed by the ſquare root of CO, inſtead of the difference between the ſquare roots of CD and QS.

The parabolic complement MIKB, being but half of the parabola ABKI, it is evident that the ſum of all the retarded velocities

velocities in filling the fecond branch will be no more than half the fum of the velocities on which we have been accuftomed to count; from whence it follows that the branch FG will require twice the time to be filled as was formerly imagined. It follows alfo, that becaufe the complement MIKB, is but one-third of the parallelogram AIMB; therefore the branch BF will be three times as long in filling as it would be with the uniform velocity expreffed by MB. And laftly it follows, that the fum of the velocities of water afcending from Q to q, inftead of being expreffed by the area of the mixed quadrilateral PO op, ought to be expreffed by the area of the quadrilateral KL lk, which may be found in the following manner.

Let $AB = a$, $nB = b$, $NB = r$ and $nN = c$. Now the uniform velocities being as the ordinates, we fhall have $AI = \sqrt{a}$, $nk = \sqrt{b}$, $NK = \sqrt{r}$, and let $b - r = c$; but $\frac{2b}{3}\sqrt{b} - \frac{2r}{3}\sqrt{r} =$ the fegment $nNKk$, and $c\sqrt{a} =$ the parallelogram $LNnl$; confequently $c\sqrt{a} - \frac{2b}{3}\sqrt{b} - \frac{2r}{3}\sqrt{r} =$ the fpace $LKkl$, or the fum of all the retarded velocities during the afcent from Q to q.

To give an example in numbers, we will fuppofe $a = 30$, $b = 24$, $r = 20$ and $c = 4$, then $8\sqrt{a} = 43.82$, $8\sqrt{b} = 39.19$, and $8\sqrt{r} = 35.78$; hence $4 \times 43.82 - \frac{2 \times 24}{3} \times 39.19 - \frac{2 \times 20}{3} \times 35.78 = 175.28 - 627.04 - 477.07 = 25.31$; but by the laws of accelerated motion, the fpaces defcribed are as the fquares of the times of defcription; wherefore $32 : 1''^2 :: 25.31 : 0.79$ and $\sqrt{0.79} = 0.89''$ = the time required for the water to afcend from Q to q = 4 feet.

DESCRIPTION OF THE STEAM-ENGINE. Fig. 3.

A. The receiver, which may be made either of wood or iron.

BBBBB. Wooden or caft-iron pipes for conveying the water to the receiver and from thence to the penftock.

C. The penftock or ciftern.

D. The water-wheel.

E. The boiler, which may be either iron or copper.
F. The hot-well for ſupplying the boiler with water.
GG. Two ciſterns under the level of the water, in which the ſmall bores BB, and the condenſer are contained.
HHH. The ſurface of the water with which the ſteam-engine and water-wheel are ſupplied.
aa. The ſteam-pipe, through which the ſteam is conveyed from the boiler to the receiver.
b. The feeding-pipe for ſupplying the boiler with hot water.
ccccc. The condenſing apparatus.
dd. The pipe which conveys the hot water from the condenſer to the hot-well.
eee. Valves for admitting and excluding the water.
ff. The injection pipe, and *g* the injection cock.
h. The condenſer.

It does not appear neceſſary to ſay any thing here on the manner in which this machine performs its operations without manual aſſiſtance, as the method of opening the cocks by which the ſteam is admitted into the receiver and condenſed, has been already well deſcribed by ſeveral writers. But it will be neceſſary to remark that the receiver, penſtock, and all the pipes, muſt be previouſly filled before any water can be delivered on the wheel, and when the ſteam in the boiler has acquired a ſufficient ſtrength, the valve at *c* is opened and the ſteam immediately ruſhes from the boiler at E into the receiver A, the water deſcends through the tubes A and B, and aſcends through the valve *e* and the other pipe or tube B into the penſtock C. This part of the operation being performed and the valve *c* ſhut, that at *a* is ſuddenly opened, through which the ſteam ruſhes down the condenſing pipe *c*, and in its paſſage meets with a jet of cold water from the injection cock *g* by which it is condenſed. A vacuum being made by this means in the receiver, the water is driven up to fill it a ſecond time through the valves *ee* by the preſſure of the external air, when the ſteam-valve at *c* is again opened and the operation repeated for any length of time the machine is required to work.

There are many advantages which a ſteam-engine on this conſtruction poſſeſſes beyond any thing of the kind hitherto invented; a few of which I ſhall beg leave to enumerate.

1. It

1. It is ſubject to little or no friction.

2. It may be erected at a ſmall expence when compared with any other ſort of ſteam-engine.

3. It has every advantage which may be attributed to Bolton and Watt's engines, by condenſing out of the receiver, either in the penſtock or at the level of the water.

4. Another very great advantage is, that the water in the upper part of the pipe adjoining the receiver, acquires a heat by its being in frequent contact with the ſteam, very nearly equal to that of boiling water; hence the receiver is always kept uniformly hot as in the caſe of Bolton and Watt's engines.

5. A very ſmall ſtream of water is ſufficient to ſupply this engine, (even where there is no fall) for all the water raiſed by it is returned into the reſervoir HHH.

From the foregoing reaſons it manifeſtly appears that no kind of ſteam-engine is ſo well adapted to give rotatory motion to machinery of every kind as this. Its form is ſimple, and the materials of which it is compoſed are cheap; the power is more than equal to any other machine of the kind, becauſe there is no deduction to be made for friction, except on account of turning the cocks which is but trifling.

Its great utility is therefore evident in ſupplying water for every kind of work performed by a water-wheel, ſuch as griſt-mills, ſaw-mills, blaſt-furnaces, forges, &c.

Dimensions of the Steam-Engine for working an overſhot wheel, accompanied with ſuch calculations as are neceſſary for aſcertaining the ſizes of its different parts, when applied to various purpoſes.

The quantity of water which this machine is intended to raiſe into the receiver in a given time, cannot be aſcertained until ſome ſtandard be fixed on for the height of the ſurface of the water in the receiver above that in the reſervoir HHH, which when known, we ſhall be enabled to calculate the diameters of the receiver and pipes with certainty.

Writers on the ſubject of hydraulics generally allow that a column of water 34 feet high is equal to the preſſure of the atmoſphere when the mercury in the barometer ſtands at 29.5 inches. Now if we admit that the water will aſcend into an exhauſted receiver

receiver to the height of 30 feet only inſtead of 34 feet, we ſhall by this means allow about 4 feet for the imperfection of the vacuum, or nearly one-eighth part of the whole power of the machine, if the ſteam in the receiver could be perfectly condenſed. Let therefore the higheſt elevation of the water in the receiver be 24 feet above the ſurface of the water in the reſervoir, and if the bottom of the receiver and the upper part of the ciſtern or penſtock be each 20 feet above the ſame level, the diameter of the water-wheel may be eaſily aſcertained when the depth of the penſtock or head of water is given.

Now as the velocity of the water is continually retarded during the time employed to fill the receiver, we muſt again have recourſe to the inverted ſyphon (Fig. 2.) in order to determine the time in which it may be filled and emptied, which when aſcertained, we ſhall be enabled to calculate the number of ſtrokes the machine may make in a minute, and conſequently the quantity of water it will deliver on any overſhot water-wheel in a given time.

The example on page 355 was purpoſely intended to ſhew the time neceſſary for filling the receiver according to the above dimenſions, where $a=30$, $b=24$, $r=20$ and $c=4$ feet; whence it appears that it may be filled in $0''.89$ to an height of 4 feet above its bottom, or 24 feet above the level of HHH.

The common ſteam-engine invented by Newcomen and Cawley, when it works to the beſt advantage, requires the ſteam to be made about one-tenth ſtronger than the ſurrounding air; but that this receiver may be emptied with ſufficient diſpatch, it will be neceſſary to increaſe the elaſticity of the ſteam at leaſt one-fourth part beyond what is produced from the uſual heat of boiling water. Admitting therefore that a column of water 34 feet in height be in equilibrio with the preſſure of the atmoſphere, we have $\frac{34}{4}=8.5$ feet, which added to 24, the higheſt elevation of the water above the ſurface of that in the reſervoir, gives 32.5 for the ſpace AB. Fig. 2. There being now but a column of 24 feet inſtead of 30 as before, preſſing againſt a counteracting column of 20 feet, the deſcent of the water in the receiver will be conſiderably ſlower than its aſcent, during the time occupied in filling it to an height of 4 feet above its bottom;

bottom; but we have ſuppoſed the increaſed elaſticity of the ſteam to be equal to a column of water 8.5 feet high, which being added to 4 feet, the difference between the two columns, makes nB in this caſe = 12.5 feet, An = 8.5 feet, nN = 4 feet, and NB = 4.5 feet. By theſe meaſurements the parallelogram $NnlL$ will be found = 113.1368, the parabola $BnkB$ = 132.1648, and the parabola BNKB = 50.9118; hence $BnkB$—BNKB = $NnkK$ = 81.253; but 113.1368—81.253 = 31.8838 = $KklL$, and $\sqrt{\frac{31.8838}{32}} = 0''.99$ or $1''$ = the time required to empty the receiver, when filled with 4 feet of water; and as it appears that it may be filled in $0''.89$ or $0''.9$ of a ſecond, it is therefore evident that this machine may make 30 ſtrokes in a minute, ſuppoſing the pipes and receiver were all of the ſame diameter; but it is not neceſſary that it ſhould exceed 10 ſtrokes per minute, and conſequently the pipes which convey the water to and from the receiver, need not be more than one-third part of its area, and on no occaſion to exceed one half.

It has been ſuppoſed, in what we have ſaid concerning the ſteam-engine, that the upper part of the penſtock is on the ſame level with the bottom of the receiver, or 20 feet above the level of the water in the reſervoir, and admitting the penſtock to be 4 feet in depth, (inſtead of 22 inches, ſee page 350) there will be a ſpace equal to 16 feet left for the diameter of the wheel; but that its motion may not be interrupted by wading through the water in the reſervoir, we have here ſuppoſed the diameter to be no more than 15 feet. Now, if each revolution of the wheel be performed in the time this machine makes one ſtroke, the circumference muſt move with a velocity equal to 7.854 feet in each ſecond of time, admitting the ſteam-engine works at the rate of 10 ſtrokes in a minute.

Previous to determining the capacity of the receiver, it will not be improper to bring into one point of view, what has already been ſaid on the ſubject of Beydler's griſt-mill and Keyger's ſaw-mill.

Beydler's griſt-mill with one pair of ſtones, where $h = 1.77$ and $a = 0.3125$.

$8aq\sqrt{h} = 20.38$ in one ſecond, and $8aqt\sqrt{h} = 122.28$ gallons, t being

t being 6 feconds. $8a\sqrt{h}=3.325$ cubic feet and $8\sqrt{h}=10.64$ feet, the uniform velocity in one fecond; alfo $haw = 34.57$ lbs. the force of impact on the wheel.

For two pair of ftones, h being $= 1.75$ and $a = 0.417$. $8aq\sqrt{h}=27$ gallons in $1''$ and $8aqt\sqrt{h}=162$ gallons in 6 feconds. $8a\sqrt{h}=4.4$ cubic feet, $8\sqrt{h}=10.584$ and $haw = 46.5$ pounds.

Keyger's faw-mill with a 4 feet head $= h$ and $a = 0.0833$. $8aq\sqrt{h}=8.2$ and $8aqt\sqrt{h}=49.2$ gallons in 6 feconds. $8a\sqrt{h}=1.32$ cubic feet, $8\sqrt{h}=16$ feet the uniform velocity in $1''$; alfo $haw = 20.8$ lbs. the force of impact.

The fame mill with a 6 feet head $= h$ and $a = 0.167$. $8aq\sqrt{h} = 20$, $8aqt\sqrt{h} = 120$, $8a\sqrt{h} = 3.273$, $8\sqrt{h} = 19.6$ and haw $= 62.6$ pounds.

If it be intended that the receiver fhall contain 122.28 gallons for one pair of ftones, and 162 gallons for two pair, we fhall find that the former number is equal to a cylinder 4 feet high by 30 inches diameter, and that latter number is equal to one of the fame height by 3 feet diameter; but to find the area of the gateway in the penftock, adapted to the fteam-engine, which is 4 feet deep inftead of 22 inches, we muft find an area x for the aperture, which fhall difcharge as much water in a given time, (which we will fuppofe to be 6 feconds) as flows through the gateway of Beydler's mill in the fame time; making therefore $H =$ the head of water at the fteam-engine, and $h =$ that of the grift-mill; alfo $a =$ the gateway as before, we have $x\sqrt{H} = a\sqrt{h}$, and $x = \dfrac{a\sqrt{h}}{\sqrt{H}} = 0.2078$ for one pair of ftones, and 0.2758 for two pair. Now Hxn being to haw nearly in the ratio of 3 to 2 for the difference of the forces of impact, we may fafely conclude that receivers of the above dimenfions will be amply fufficient for fupplying the water-wheel with a power as much fuperior to Beydler's mill, as the difference between the forces of impact will amount to.

With refpect to Keyger's faw-mill we fhall only remark, that as the quantity of water paffing over the wheel with a 6 feet head, is fo nearly equal to that which Beydler's mill requires for one pair of ftones, that a receiver of equal dimenfions will be found fufficiently large, the penftock of the fteam-engine being alfo 6 feet deep.

It will not be neceſſary that in any caſe the boiler ſhould contain more than 6 times as much as the receiver; hence we have for Beydler's mill with one pair of ſtones, and Keyger's ſaw-mill with 6 feet head, a receiver = 4 feet by 2.5 diameter = to 122.28 gallons, which multiplied by 6 = about 734 gallons for the contents of the boiler. The receiver for the ſame griſt-mill = 4 feet by 3 feet = 162 gallons, and the boiler = 972 gallons.

In order to prevent the water, whilſt the receiver is filling, from ſtriking againſt its top, it will be neceſſary that one foot at leaſt be added to its height; ſo that inſtead of being 4 feet high as we have hitherto ſuppoſed, it ſhould be at leaſt 5 feet.

Fig. 1.

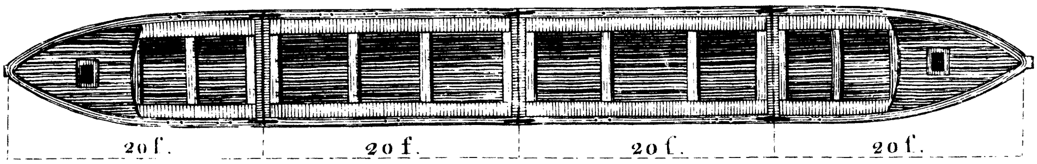

Fig. 2.

Fig. 3.

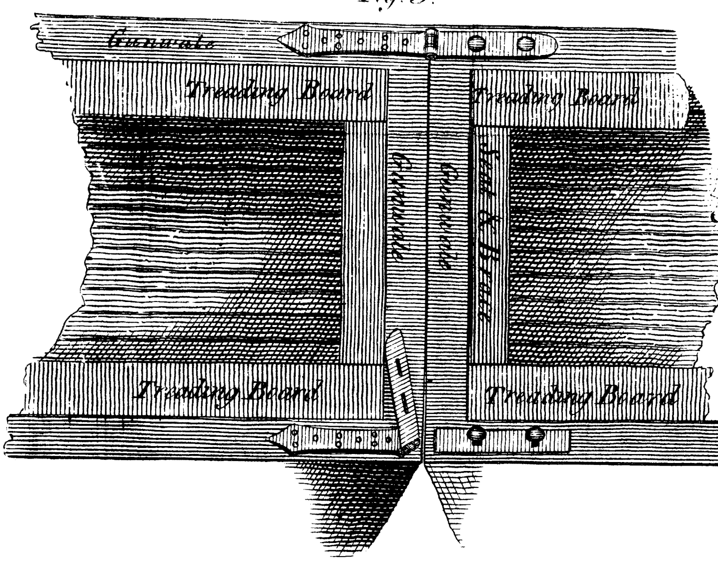

Fig. 3.
P. 356.